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Effective two-body forces in light and medium mass nuclei

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Abstract. From the spectroscopic information provided by single particle stripping reactions, we have extracted average effective two-body interaction between nucleons in the *p*-, *sd*-, and *fp*- shells. Using the derived interaction parameters, we have calculated the energy centroids of the level spectra of residual nuclei obtained via single nucleon stripping reactions involving light and medium mass nuclei as targets.

Keywords. Effective two-body interaction; energy centroids; stripping reactions.

1. Introduction

Direct transfer reactions are very important probes for the investigation of nuclear structure. Apart from the energy spectra of the residual nuclei, they yield valuable information regarding the occupancies (French and Macfarlane 1961), multipole moments of the target state (French 1964; Kumar and Bansal 1975), and the nature of the effective two-body interaction between nucleons. Equations relating the average (over angular momentum but not over isospin) effective two-body matrix elements to the isospin energy centroids have been given by Bansal (1972); we use these equations to extract, from the experimental data, the best possible information about the iso-singlet and iso-triplet two-body force parameters (*J*-averaged matrix elements) in the region of light and medium mass nuclei. These parameters serve as constraints on the nature of the detailed two-body interaction, and thus their usefulness to the nuclear structure physicist cannot be underestimated. The present paper presents a list of these, as extracted from the experimental data and compares them with those calculated from the KB interaction (Kuo and Brown 1966 and 1968) and other phenomenological interactions (Cohen and Kurath 1965; Federman and Pittel 1970; Lips and McEllistren 1970; Halbert *et al* 1971; Glaudemans *et al* 1972; Schiffer and True 1976).

2. Theory

We label the target state, in a transfer reaction experiment, as $|n_0 J_0 T_0 x_0\rangle$ where J_0 and T_0 are, respectively, the angular momentum and isospin of the state; n_0 is the number of active nucleons and x_0 stands for all the other quantum numbers required to specify the state uniquely. By doing a single-particle transfer reaction on this

state, it is possible, in general, to populate states in the residual nucleus having isospin $T_<(\equiv T_0-\frac{1}{2})$ as well as the states having isospin $T_>(\equiv T_0+\frac{1}{2})$. For the case of a single particle stripping reaction, $S_{JT}{}^{(+)}$ and $E_{JT}{}^{(+)}$ denote the spectroscopic factor and energy, respectively, of a state in the residual nucleus having angular momentum J and isospin T; the energy centroid of the levels having the same isospin T may be defined as

$$\overline{E}^{(+)}_T = \sum_J (2J+1)S_{JT}{}^{(+)}\, E_{JT}{}^{(+)} \Big/ \sum_J (2J+1)S_{JT}{}^{(+)} \tag{1}$$

If the target state has many active orbits which we label by j and a nucleon is added into the orbit i which is free from protons (this restriction should be noted), then the energy centroid of the levels of the residual nucleus, according to Bansal (1972), is related to the average two-body interaction by the equation

$$\overline{E_T{}^{(+)}} = \Bigg[\sum_j \Big\{ p_T{}^{(+)}(i-j) + (N_i-\delta_{ij}) q_T{}^{(+)}(j)\, \overline{W^{T=1}_{i-j}} + (N_i+\delta_{ij}) r_T{}^{(+)}(j)\, \overline{W^{T=0}_{i-j}} \Big\} \Big/ \sum_J \left(\frac{2J+1}{2J_0+1}\right) S_{JT}{}^{(+)} \Bigg] + E^{(+)}(riz) \tag{2}$$

where

$$p_T{}^{(+)}(i-j) = -\tfrac{1}{2}(1+\delta_{ij})E_t(i-j)\left\{1+\frac{f(T)}{T_0}\right\}; \tag{3}$$

$$q_T{}^{(+)}(j) = \tfrac{3}{4}n_j + \frac{f(T)T_{0j}}{2T_0}; \tag{4}$$

and

$$r_T{}^{(+)}(j) = \tfrac{1}{4}n_j - \frac{f(T)T_{0j}}{2T_0} \tag{5}$$

In the above equations:

(i) n_j is the number of nucleons occupying the jth active orbit in the target state ($\sum_j n_j = n_0$).

(ii) T_{0j} is the contribution to the target state isospin T_0 from nucleons in the jth active orbit.

(iii) $E_t(i-j)$ is the contribution to the target state energy arising from the interaction of nucleons in the ith active orbit with those in the jth active orbit.

(iv) $E^{(+)}(riz)$ is the energy of the ' residual interaction zero ' state, that is, the state of the residual nucleus obtained when the interaction between the added nucleon and the other active nucleons is switched off.

(v) $\overline{W^{T=1}_{i-j}}$ and $\overline{W^{T=0}_{i-j}}$ are the average interaction energies in the iso-triplet and iso-singlet states, respectively, of one nucleon in the orbit i and another in the orbit j. These are defined as

$$\overline{W^{T}_{i-j}} = \sum_J (2J+1) \langle (ij)_{JT} | H_{\text{int.}} | (ij)_{JT} \rangle / \sum_J (2J+1)$$

where $H_{\text{int.}}$ is the effective two-body interaction part of the Hamiltonian.

(vi) $$f(T) = T(T+1) - \tfrac{3}{4} - T_0(T_0+1); \tag{6}$$

and $$N_i = 2j_i + 1 \tag{7}$$

(vii) (+) sign with various quantities is to remind us that we are dealing with a stripping (addition) reaction.

3. Method of calculation

We have used eqs (1) through (7) to derive $\overline{W^{T=1}_{i-j}}$ and $\overline{W^{T=0}_{i-j}}$ parameters from the experimentally measured centroid energies in single particle stripping reactions on *p*-, *sd*-, and *fp*-shell target states. These include the ground states of the nuclei ^{9,10}Be in the *p*-shell; ^{18}O, ^{21,22}Ne, ^{25,26}Mg, ^{29,30}Si and $^{32\text{-}34}$S in the *sd*-shell; $^{41\text{-}44,46,48}$Ca, ^{46,48,50}Ti, ^{50,52,54}Cr, ^{55}Mn, ^{54,56}Fe, ^{58,60,62,64}Ni, ^{63,65}Cu and ^{64,66}Zn in the *fp*-shell. The references, for the experimental information used, are listed in column 5 of table 3. The present calculation assumes a pure configuration for the target state. The quantities $E^{(+)}$ (*riz*) and $E_j(i-j)$ are calculated with the help of the binding energy tables. The denominator on the r.h.s. of eq. (2) is given by the well-known non-energy-weighted sum rules (French and Macfarlane 1961).

As an example, consider the centroid $\overline{E_{3/2}{}^{(+)}}$ of the $T=3/2$ levels in ^{57}Co excited via ^{56}Fe(^{3}He,d)^{57}Co reaction, the proton being added to the $2p_{3/2}$ orbit. Taking ^{40}Ca as the closed core, the target state configuration is assumed to be 6 protons and 8 neutrons in the $1f_{7/2}$ orbit and the remaining 2 neutrons in the $2p_{3/2}$ orbit. With $1f_{7/2}$ and $2p_{3/2}$ as the active orbits in the target state, eq. (2) reduces to

$$\overline{E^{(+)}_{3/2}} = \Big[\Big\{ p_{3/2}{}^{(+)}(\tfrac{3}{2}-\tfrac{7}{2}) + N_{3/2} q_{3/2}{}^{(+)}(\tfrac{7}{2})\, \overline{W^{T1}_{3/2-7/2}} + N_{3/2} r_{3/2}{}^{(+)}(\tfrac{7}{2})\, \overline{W^{T0}_{3/2-7/2}} + p_{3/2}{}^{(+)}(\tfrac{3}{2}-\tfrac{3}{2})$$

$$+ (N_{3/2}-1) q_{3/2}{}^{(+)}(\tfrac{3}{2})\, \overline{W^{T1}_{3/2-3/2}} + (N_{3/2}+1) r_{3/2}{}^{(+)}(\tfrac{3}{2})\, \overline{W^{T0}_{3/2-3/2}} \Big\} \Big/ \sum_J \Big(\frac{2J+1}{2J_o+1} \Big) S_{J3/2}{}^{(+)} \Big]$$

$$+ E^{(+)}(\text{riz}) \tag{8}$$

The energy of the ' residual interaction zero ' state is given by

$$E^{(+)}(\text{riz}) = -\text{B.E. } (^{56}\text{Fe}) + \epsilon_{3/2}(p) + E_c + \text{B.E. } (^{57}\text{Co}) \tag{9}$$

where $\epsilon_{3/2}(p)$ is the energy of a $p_{3/2}$-proton with respect to the ^{40}Ca core and E_c is the Coulomb energy due to the interaction of the added proton with the active protons in the target state. The interaction energies $E_t(3/2-7/2)$ and $E_t(3/2-3/2)$ are given by

$$E_t(\tfrac{3}{2}-\tfrac{3}{2}) = -[\text{B.E.}(^{56}\text{Fe}) - \text{B.E.}(^{54}\text{Fe}) - 2\{\text{B.E.}(^{55}\text{Fe}) - \text{B.E.}(^{54}\text{Fe})\}] \quad (10)$$

$$E_t(\tfrac{3}{2}-\tfrac{7}{2}) = -[\text{B.E.}(^{56}\text{Fe}) - \text{B.E.}(^{54}\text{Fe})] - 2\epsilon_{3/2}(n) - E_t(\tfrac{3}{2}-\tfrac{3}{2}) \quad (11)$$

The denominator in eq. (8) for the present case has the value

$$\sum_J \left(\frac{2J+1}{2J_0+1}\right) S_{J_{3/2}}{}^{(+)} = (p\text{-holes})_{3/2} + \frac{(p\text{-holes})_{3/2} - (n\text{-holes})_{3/2}}{2T_0}$$

$$= N_{3/2} + \frac{n_{3/2}}{2T_0}. \quad (12)$$

From the assumed configuration for ^{56}Fe, it is easily seen that the values of $n_{7/2}$, $n_{3/2}$, $T_{07/2}$, $T_{03/2}$ are 14, 2, 1, and 1 respectively. Remembering also that $T_0=2$ and $T=\frac{3}{2}$, all the co-efficients of W's in eq. (8) can be easily calculated with the help of eqs (3)-(7). For this specific case, we get

$$\overline{E^{(+)}_{3/2}} = \Big[\Big\{ -1{\cdot}517 + 4\times 9{\cdot}75\, \overline{W^{T=1}_{3/2-7/2}} + 4\times 4{\cdot}25\, \overline{W^{T=0}_{3/2-7/2}} - 0{\cdot}952$$

$$+ 3\times 0{\cdot}75\, \overline{W^{T=1}_{3/2-3/2}} + 5\times 1{\cdot}25\, \overline{W^{T=0}_{3/2-3/2}} \Big\} \Big/ 4{\cdot}5 \Big] + 8{\cdot}702. \quad (13)$$

If the value of $\overline{E^{(+)}_{3/2}}$ is taken from experiment, this forms *one of the equations* used to determine the W's. Usually a large amount of experimental data is available, so that, for a particular set of the parameters W, the number of equations exceeds the number of these parameters themselves. In such cases, the equations are solved by the method of least squares to obtain the values of average two-body interaction parameters W. Once the W's are known, the centroids can easily be calculated with the help of the equations given in last section.

4. Results and discussion

The results of our calculation of the average two-body interaction parameters are shown in table 1. For comparison, we have also listed the corresponding numbers obtained from the two-body matrix elements derived from a realistic interaction (Kuo and Brown 1966 and 1968) and other phenomenological interactions designed to fit experimental data (Cohen and Kurath 1965; Federman and Pittel 1970; Lips and McEllistren 1970; Halbert *et al* 1971; Glaudemans *et al* 1972; Schiffer and True 1976). The χ^2 and the root-mean-square deviation for each set of experimental data

Table 1. Average interaction parameters $\overline{W^{T=1}_{i-j}}$ and $\overline{W^{T=0}_{i-j}}$

Orbit i	Orbit j	$\overline{W^{T=1}_{i-j}}$ (MeV)				$\overline{W^{T=0}_{i-j}}$ (MeV)			
		Present Calc.	KB[a]	Others		Present Calc.	KB[a]	Others	
$1p_{1/2}$	$1p_{3/2}$	0·223		−0·260[b]		−4·785		−4·830[b]	
$2s_{1/2}$	$1d_{5/2}$	0·520	−0·439	−0·066[c]	−0·107[d]	−3·084	−2·413	−2·974[c]	−3·664[d]
$2s_{1/2}$	$2s_{1/2}$	−0·537	−1·949	−1·725[c]	−0·584[d]	−2·224	−3·184	−4·322[c]	−3·277[d]
$1d_{3/2}$	$1d_{5/2}$	0·789	−0·642	−0·375[c]	−0·107[d]	−4·806	−3·619	−2·182[c]	−3·664[d]
$1d_{3/2}$	$2s_{1/2}$	0·652	−0·123	−0·067[c]	−0·107[d]	−2·993	−2·235	−2·974[c]	−3·664[d]
$1d_{3/2}$	$1d_{3/2}$	−0·356	−0·070	−0·035[c]	−0·266[d]	−2·216	−1·952	−2·380[c]	−3·432[d]
$1f_{7/2}$	$1f_{7/2}$	−0·215	−0·128	−0·240[e]	−0·228[f]	−1·714	−1·154	−1·594[h]	−1·739[i]
$2p_{3/2}$	$1f_{7/2}$	0·267	−0·104	−0·501[e]	0·151[f]	−1·738	−0·968		
$2p_{3/2}$	$2p_{3/2}$	−0·255	−0·518	0·111[g]		−1·503	−1·474		
$1f_{5/2}$	$1f_{7/2}$	0·257	−0·225	0·210[e]		−2·285	−1·633		
$1f_{5/2}$	$2p_{3/2}$	0·432	−0·007	0·200[g]		−2·163	−0·970		
$1f_{5/2}$	$1f_{5/2}$	−0·174	0·049	0·147[g]		−1·235	−0·951		
$2p_{1/2}$	$1f_{7/2}$	0·196	−0·141			−1·591	−1·069		

(a) From Kuo and Brown 1966 and 1968
(b) (8-16) 2 BME of Cohen and Kurath 1965
(c) The Hamiltonian ' RIP ' of Halbert *et al* 1971
(d) The Hamiltonian ' MSDI ' of Halbert *et al* 1971
(e) From Lips and McEllistren 1970
(f) From Federman and Pittel 1970
(g) From Glaudemans *et al* 1972
(h) Matrix elements determined directly from experimental data by Schiffer and True 1976
(i) Matrix elements derived from a potential fitted to the experimental data by Schiffer and True 1976

used to extract the present effective interaction parameters are given in table 2, and the values of the energy centroids calculated with our interaction parameters are shown in table 3. A look at these two tables shows that the extracted parameters reproduce the experimental centroids quite well.

The results given in table 1 indicate that the iso-singlet ($T=0$) interaction parameters derived by us (column 7) are in fair agreement with those obtained from other phenomenological interactions (columns 9 and 10); the Kuo-Brown force (column 8) is, however, generally weaker (less attractive). This weak feature of the Kuo-Brown average two-body interaction is due to its having been calculated in a comparatively larger vector space, as compared to the one in which we make our calculations. The numbers in column 9, compare reasonably well with the presently calculated set (column 7), with the exception of $2s_{1/2}$—$2s_{1/2}$ and $1d_{3/2}$—$1d_{5/2}$ matrix elements. The average two-body interaction parameters obtained by fitting a modified-surface-delta interaction to experimental spectra (column 10) are somewhat stronger than the presently calculated ones (column 7), again perhaps because of the tendency of the surface-delta interactions to effectively shrink the vector space.

Table 2. χ^2 values and root-mean-square deviations for various sets of experimental data used to derive the interaction parameters.

Derived interaction parameters	Number of fitted centroids	χ^2	rms deviation (MeV)
$\overline{W^{T=1}}$ and $\overline{W^{T=0}}$ $(1\,p_{1/2}-1\,p_{3/2})$	2	—	—
$\overline{W^{T=1}}$ and $\overline{W^{T=0}}$ $(2\,s_{1/2}-1\,d_{5/2})$	3	0·040	0·245
$\overline{W^{T=1}}$ and $\overline{W^{T=0}}$ $(2\,s_{1/2}-2\,s_{1/2})$	2	—	—
$\overline{W^{T=1}}$ and $\overline{W^{T=0}}$ $(1\,d_{3/2}-1\,d_{5/2})$	2	—	—
$\overline{W^{T=1}}$ and $\overline{W^{T=0}}$ $(1\,d_{3/2}-2\,s_{1/2})$	2	—	—
$\overline{W^{T=1}}$ and $\overline{W^{T=0}}$ $(1\,d_{3/2}-1\,d_{3/2})$	3	0·051	0·046
$\overline{W^{T=1}}$ and $\overline{W^{T=0}}$ $(1\,f_{7/2}-1\,f_{7/2})$	6	0·168	0·191
$\overline{W^{T=1}}$ and $\overline{W^{T=0}}$ $(2\,p_{3/2}-1\,f_{7/2})$	13	0·593	0·184
$\overline{W^{T=1}}$ and $\overline{W^{T=0}}$ $(2\,p_{3/2}-2\,p_{3/2})$	6	0·050	0·048
$\overline{W^{T=1}}$ and $\overline{W^{T=0}}$ $(1\,f_{5/2}-1\,f_{7/2})$	3	0·006	0·086
$\overline{W^{T=1}}$ and $\overline{W^{T=0}}$ $(1\,f_{5/2}-2\,p_{3/2})$	5	0·339	0·289
$\overline{W^{T=1}}$ and $\overline{W^{T=0}}$ $(1\,f_{5/2}-1\,f_{5/2})$	6	0·242	0·054
$\overline{W^{T=1}}$ and $\overline{W^{T=0}}$ $(2\,p_{1/2}-1\,f_{7/2})$	8	0·177	0·263

Table 3. Calculated and experimental isospin centroid energies (in MeV) with respect to ground states of residual nuclei.

Transfer orbit	Residual nucleus (Target+nucleon)	$\overline{E_T{}^{(+)}}$ Calc.	$\overline{E_T{}^{(+)}}$ Expt.	Reference for experimental result
	(a) Centroids of $T_<$ states $\overline{E_{T_<}{}^{(+)}}$			
$1\,p_{1/2}$	^{9}Be+p	5·569	5·568	Auton 1970
$2\,s_{1/2}$	^{18}O+p	3·526	3·687	Schmidt and Duhm 1970
	^{25}Mg+p	1·893	1·746	Weidinger *et al* 1968
	^{29}Si+p	0·627	0·627	Hertzog *et al* 1974
$1\,d_{3/2}$	^{22}Ne+p	4·958	4·958	Powers *et al* 1971
	^{26}Mg+p	2·900	2·900	Lutz *et al* 1970
	^{30}Si+p	1·766	1·766	Lutz *et al* 1970
	^{33}S+p	0·649	0·649	Erskine *et al* 1971
$1\,f_{7/2}$	^{43}Ca+p	1·826	1·416	Schwartz 1968
	^{48}Ca+p	0·040	0·000	Erskine *et al* 1966
$2\,p_{3/2}$	^{48}Ca+p	3·367	3·543	Erskine *et al* 1966
	^{50}Ti+p	3·015	2·633	Maheshwari *et al* 1971
	^{50}Cr+p	2·920	2·400	Cujec and Szöghy 1969
	^{52}Cr+p	2·736	2·800	Cujec and Szöghy 1969
	^{54}Cr+p	2·562	2·520	Cujec and Szöghy 1969
	^{54}Fe+p	2·440	2·655	Roussel *et al* 1970
	^{56}Fe+p	1·686	1·654	Hardie *et al* 1972
	^{58}Ni+p	0·254	0·189	Watson and Britton 1973
	^{60}Ni+p	0·182	0·253	Watson and Britton 1973

Table 3. (*contd.*)

Transfer orbit	Residual nucleus (Target+nucleon)	$\overline{E_T^{(+)}}$ Calc.	$\overline{E_T^{(+)}}$ Expt.	Reference for experimental result
$1f_{5/2}$	^{48}Ca+p	4·651	4·692	Erskine *et al* 1966
	^{54}F +p	3·664	3·622	Vourvopoulos *et al* 1969
	^{58}Ni+p	1·467	1·302	Watson and Britton 1973
	^{60}Ni+p	1·111	1·213	Watson and Britton 1973
	^{62}Ni+p	1·303	1·437	Watson and Britton 1973
	^{64}Ni+p	1·447	1·695	Watson and Britton 1973
	^{64}Zn+p	0·711	0·399	Betigeri *et al* 1967
	^{66}Zn+p	0·866	0·734	Betigeri *et al* 1971
$2p_{1/2}$	^{48}Ca+p	5·960	6·017	Erskine *et al* 1966
	^{50}Ti+p	5·466	5·360	Maheshwari *et al* 1971
	(b) Centroids of $T>$ states $\overline{E_{T>}^{(+)}}$			
$1p_{1/2}$	^{10}Be+n	0·320	0·319	Crosby and Legg 1967
$2s_{1/2}$	^{21}Ne+n	6·090	6·453	Neogy *et al* 1972
	^{29}Si+p	2·314	2·314	Hertzog *et al* 1974
$1d_{3/2}$	^{32}S+n	0·402	0·403	Mermaz *et al* 1971
	^{33}S+n	2·416	2·480	Crozier 1972
	^{34}S+n	0·049	0·000	Van Der Baan and Leighton 1971
$1f_{7/2}$	^{41}Ca+n	2·894	2·818	Hansen *et al* 1975
	^{42}Ca+n	0·102	0·066	Brown *et al* 1974
	^{43}Ca+n	2·940	2·742	Bjerregaard and Hansen 1967
	^{44}Ca+n	0·270	0·315	Brown *et al* 1974
$2p_{3/2}$	^{42}Ca+n	2·202	2·064	Brown *et al* 1974
	^{46}Ca+n	2·615	2·285	Bjerregaard *et al* 1965
	^{46}Ti+n	2·208	2·438	Chowdhury and Sengupta 1974
	^{48}Ti+n	2·011	2·085	Ball *et al* 1972
	^{50}Ti+n	0·778	0·398	Kocher and Haeberli 1972
	^{50}Cr+n	1·658	2·080	Delic and Robson 1969
	^{52}Cr+n	0·870	0·985	Delic and Robson 1969
	^{54}Fe+n	0·757	0·926	Kocher and Haeberli 1972
	^{56}Fe+n	1·002	1·016	Sengupta *et al* 1971
	^{58}Ni+n	0·413	0·370	Aymar *et al* 1973
$1f_{5/2}$	^{50}Ti+n	3·541	3·677	Wilhjelm *et al* 1968
	^{55}Mn+n	2·257	2·195	Comfort 1969
	^{56}Fe+n	1·618	2·067	Sengupta *et al* 1971
	^{58}Ni+n	0·943	0·525	Aymar *et al* 1973
	^{63}Cu+n	0·821	0·901	Park and Daehnick 1969
	^{65}Cu+n	0·934	0·790	Daehnick and Park 1969
$2p_{1/2}$	^{46}Ti+n	3·800	3·980	Kocher and Haeberli 1972
	^{48}Ti+n	3·461	3·559	Kocher and Haeberli 1972
	^{50}Ti+n	2·086	1·903	Kocher and Haeberli 1972
	^{50}Cr+n	3·184	3·592	Macgregor and Brown 1972
	^{52}Cr+n	2·254	1·975	Kocher and Haeberli 1972
	^{54}Fe+n	2·217	2·090	Kocher and Haeberli 1972

In the case of the much weaker iso-triplet ($T=1$) effective interaction, there are large differences among the various sets of parameters (column 3-6 of table 1); for some of the parameters even the signs differ. However, the average effective interaction derived by us (column 3) does exhibit some symmetry in the sense that it is attractive for two nucleons in the same orbit and is repulsive when the nucleons are in different orbits. We shall prefer to defer the explanation of the existence of this symmetry in our results as well as a critical comparison of our results with the results obtained by others (columns 4-6), till some work is done in the regions of the periodic table other than the ones presently investigated, and a more detailed investigation of the nuclei reported in this paper is carried out.

Within the framework of the model chosen by us, the uncertainties in our calculation of the average interaction parameters are mainly due to the errors in the experimental determination of the centroid-energies which in turn depend upon the experimental errors in the energies and the spectroscopic factors of the individual levels. The energies can be measured fairly accurately but, even the best measurements of the spectroscopic factors suffer from an uncertainty of the order of 10% or more. Though some of these errors get averaged out in the sum-rule methods employed to extract the effective two-body force parameters, the calculated values hide in themselves the uncertainties inherent in the extraction of the spectroscopic factors, S_{JT}. In this sense, the values of the force parameters are somewhat time-dependent and should change as the values of S_{JT} improve. We are also aware of the fact that the present calculations do not seem to take into account the off-diagonal contributions. Such contributions are zero for the simple (non-configuration-mixed) target states considered in the present work. When the target states are complex (configuration-mixed-states), then the off-diagonal contributions can be important and we have to take those into consideration. On this subject we plan to report later.

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